LEARNING IN THE MAKING

How To

Plan, Execute, and Assess Powerful Makerspace Lessons

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CHAPTER 1

The Precedent for Maker Education

Humans have had a need to create and make since the beginning of their time on Earth. A lot of that making had to do with survival—making tools for agrarian and hunting cultures, for their homesteads, and for keeping themselves and their families safe from human and animal predators. Their acts of creativity also revolved around making for the pure joy of it. For example, people have long decorated pottery and made petroglyphs, sculptures, jewelry, and clothing. Making is an innate human need and desire.

A characteristic of the 20th century was the advent of mass production and the factory assembly line. Products that used to be handmade by individuals were suddenly made through standardized manufacturing processes that efficiently pumped out products in great quantity. Mass production is typically characterized by some type of mechanization, such as an assembly line, to achieve high volume, detailed organization of materials flow, careful control of high-quality standards, and division of labor (Kenton, 2019). One of the biggest benefits of mass production was the ability to produce large quantities of products at a minimal cost. However, one of the casualties was the widespread art of handmade products tailored to individual desires and specifications.

Arguably, another casualty was the carryover of a mass production mentality into education settings. Since the 19th century, the United States and other countries have adopted the Prussian model of teaching, also known as the factory model school. "We would recognize the manifestation of this model fairly easily: a teacher at the front of the room, and neat rows of desks with students sitting in front of him/her. The purpose of this structure is fairly simple: the teacher is giving students information in 'assembly-line fashion,' and the students—through memorization, repetition, and eventually testing—hopefully retain it" (Hochdorf, 2016, para. 2).

Making is essential to the human experience, but it hasn't been a part of classical education or a focus of Western education. Hands-on learning, innovating, making, and creating in the school environment has been a casualty of this movement. Nevertheless, several events have converged in the past few years as a type of backlash against mass-produced products and education, which has helped to birth the maker movement and the maker education movement in both formal and informal educational settings.

The maker movement is a relatively new phenomenon—built from familiar pieces—but its relevance to education has deep roots. It has long been stated that children and youth can learn by playing and building with interesting materials and tools (Montessori, 1912 as cited in Martin, 2015, p. 31).

Making often fosters learning in a variety of ways that directly connects with long-established theories of how learning occurs. "For example, testing ideas out in the world allows one to check expectations against reality, a process that can create conceptual disequilibrium, and can in turn lead to conceptual adaptation" (Piaget, 1950 as cited in Martin, 2015, p. 31). Physical creations also create a context for social engagement around a shared endeavor. "This can bring more- and less-experienced participants together around a common task—a configuration that often proves fruitful for learning" (Martin, 2015, p. 31).

The philosophy driving the maker movement is as old as the human species. Today's vibrant, passionate, and active maker movement builds on this tradition. *Make:* magazine (founded in 2005 by Dale Dougherty) and the many Maker Faires that occur around the world have helped popularize the maker movement and propel it forward. In true open-source form, the whole movement brings together diverse communities involved in the process of creating things through hands-on efforts—from sewing to 3D printing. Makers represent a growing community of builders and creators—engineers, scientists, artists, DIYers, and hobbyists of all ages, interests, and skill levels—who engage in experimentation, collaboration, and innovation (Singh, 2018).

The maker movement was born out of several events that converged to create the environment we see today:

- The do-it-yourself (DIY) movement.
- A focus on STEM and STEAM education.
- A push for 21st century skills and competencies.
- Information access and abundance.
- Affordable maker technologies.
- A crowdsourcing and participatory culture.
- Open-source resources.

The Do-It-Yourself (DIY) Movement

Do it yourself, or DIY, is a term used by various communities of practice that focus on people creating things for themselves without the aid of paid professionals. The DIY movement emerged partially from a revolt against high-priced consumerism, and its popularity can be indirectly measured through the marked increase of classes offered by retail stores such as Home Depot, Lowes, and Michaels and through the increasing popularity of DIY websites such as Instructables (www.instructables.com), *Make:* magazine (https://makezine.com/projects), and DIY for younger makers (https://diy.org). DIY offers many benefits and life skills, such as developing ingenuity, learning from mistakes, realizing financial savings, customizing objects, having fun, and using one's own brain and hands. Making things is about personalization, and therein lies the value of DIY. One's creativity and skills develop along with a sense of art and logic.

Young people are growing up in a DIY culture where they have role models who engage in DIY and have immediate access to information, tutorials, and technological resources online. It follows that the DIY culture is influencing teachers' and students' desire to make and create for themselves both within and outside of educational settings.

A Focus on STEM and STEAM Education

There is a growing need in workplace settings for employees to possess STEM and STEAM related skills. As such, there has been a push for STEM and STEAM education in school curricula and afterschool programs. Science, technology, engineering, and math skills—with an added focus on the arts—prepare learners not only for many different jobs but also to have richer personal lives now and in the future. Evans and Milgrom-Elcott (2017) state, "Whatever today's kids want to be able to do tomorrow, they will need serious STEM skills" (para. 10). This includes the ability to use their skills to tackle new dilemmas and solve new problems. This "will be true whether they become a mechanic called in to fix something they've never seen before, or a medical professional faced with an outbreak of a new disease" (para. 10). Education needs to be about helping young people acquire the skills they'll need to live successful, productive, and satisfactory lives. In this "rapidly changing world, where it's difficult to predict what challenges and technologies lie ahead, it is more important than ever that kids learn to think carefully, critically, and creatively" (para. 17).

Maker education can be a gateway to STEM disciplines for students who may not have had an interest in science, technology, engineering, or math. Teachers have reported that making can be a great way to get students excited and engaged in their learning. Many projects in subject-area classes incorporate making and a variety of STEM topics. "Students working on designing and building furniture for their classroom use algebra and geometry to figure out the dimensions. E-textiles and soft circuitry, in which circuits are sewn using conductive thread or fabric, have shown to be an engaging way to teach electronics and programming, especially for young women. The possibilities for ways to incorporate making into the school day are endless, and it is exciting to see what teachers have been developing and sharing" (Thomas, 2012, para. 6).

STEAM, in which the arts are integrated into STEM, has been touted as an important addition to STEM education. Educators can situate learners for future careers by bringing STEM and STEAM into the learning environment. In addition, STEM and STEAM integrates cross-curricular standards, including those specified by the Next Generation Science Standards and the Common Core State Standards in both math and science, lending credibility to its implementation by teachers.

A Push for 21st Century Skills and Competencies

The Partnership for 21st Century Learning (a network of Battelle for Kids) has developed a framework that identifies four learning and innovation skills—creativity, critical thinking, communication, and collaboration—that are essential to prepare students for the increasingly complex life and work environments of the 21st century (Battelle for Kids, n.d.).

Many schools have embraced these skills and include them in the standards they expect students to learn. The National Education Association (NEA, n.d.) has stated, "All educators want to help their students succeed in life. What was considered a good education 50 years ago, however, is no longer enough for success in college, career, and citizenship in the 21st century" (para. 1). As such, the NEA recommends the implementation of the "four *C*s" as developed and disseminated by the Partnership for 21st Century Learning.

At the 2018 Maker Faire in New York City, the young cast of *Mythbusters Jr* (ages 13–15) were asked, "What skills do you think you need to be a maker?" They mentioned creativity, teamwork (collaboration), and communication—three out of the four learning and innovation skills identified by the Partnership for 21st Century Learning.

Information Access and Abundance

We are living in one of the most exciting times in the history of humankind. Our world is filled with an abundance of information—and access to it has never been easier. We have technologies to access any type of information and get assistance and feedback from people around the world. We also have the ability to create products that match (and exceed) our imaginations. The internet grants access to all kinds of information, resources, and tutorials. For example, DIYers can go online to find information and tutorials via YouTube, Wikipedia, and various social networks. There are YouTube channels (and other websites) for sparking curiosity and inspiring creativity, for learning how to use different technologies, for exploring and learning about different science and math concepts, and for learning different types of arts.

Young makers have taken advantage of this easy and free access to make valuable contributions to the world. For example, Jack Andraka, as a high school sophomore, discovered a test for pancreatic cancer by reading science research he found online (Tucker, 2012). Ninth grader Katherine Wu invented the driver's companion, a device that could monitor drivers' blinks and brain waves to see if they were in danger of falling asleep at the wheel. She studied neuroscience to find out how to identify signs of sleepiness and took an online course to learn how to create the computer code that would recognize those signs (Kaplan, 2014).

In terms of maker education and the bigger picture of self-directed learning, this information abundance and access means the teacher no longer needs to be the sole content expert on every topic. Their role can change into that of facilitator. Indeed, their trepidation about bringing maker education into the learning environment could be reduced due to all the information and tutorials available to students.

Affordable Maker Technologies

Maker technologies, such as 3D printers, laser cutters, Arduinos, Raspberry Pis, micro:bits, Hummingbird kits, and other robotics and computer kits, provide relatively inexpensive opportunities for learners to experiment and invent for themselves. Most are accessible and usable by students possessing a wide range of skills and age levels. The availability of affordable tools and technologies and the ability to share inventions and resources online "has fueled this evolutionary spurt in this facet of human development. New tools that enable hands-on learning—3D printers, robotics, microprocessors, wearable computers, e-textiles, 'smart' materials and new programming languages—are giving individuals the power to invent" (Martinez & Stager, 2019, para. 2).

Accessibility of these affordable maker technologies is due, in part, to the democratization of the field and medium. "When used in the context of the maker movement, 'democratization' refers to the decreasing cost of the tools and technologies credited with spurring the movement" (Britton, 2014, para. 12). Even though there is a cost attached to them, these tools and technologies are more accessible to those with fewer financial resources than similar ones were in the past. This results in the increased potential of anyone, anywhere, to be a maker, an inventor, and an innovator—including students coming from lower income and marginalized populations.

A Crowdsourcing and Participatory Culture

The maker movement and makerspaces are driven by principles of crowdsourcing and participatory cultures. Makers, as a group, freely share their projects so others can replicate and/or improve upon them. Adam Savage (of *Mythbusters* fame) has defended "sharing as a vital aspect of maker culture that is intrinsic to the underlying ethos of what it means to be a maker, and by extension, a human being" (quoted in Frauenfelder, 2018, para. 2). This type of sharing is a trademark of a participatory culture.

Many maker movement initiatives are rooted in the idea of participatory culture, a term coined by media expert Henry Jenkins. Jenkins identified the key elements of a participatory culture to include low barriers to engagement and expression, support for creating and sharing one's creations with others, and informal types of mentorship whereby those with the most experience pass along information, strategies, and resources to beginners (Fleming, 2015).

Dale Dougherty, considered by many to be the father of the maker movement, has stated, "The Maker Movement is spurred by… the increasing participation of all kinds of people in interconnected communities, defined by interests and skills online as well as hyper-local efforts to convene those who share common goals" (Dougherty, n.d., para. 1). Likewise, Massimo Banzi, inventor of the popular technology Arduino, has noted how a participatory maker culture spurs creativity. Whenever a tool is designed that allows people to be creative, there are also people who start to be creative with that tool. This is a world where people become more involved in the creation of products (Orsini, 2014).

Open-Source Resources

Open-source software is software that can be freely used, changed, and shared (in modified or unmodified form) by anyone at any time and for any reason. It is created and developed by diverse populations and distributed under licenses that comply with this open-source definition. Makers often share their projects so others can reproduce and/or improve upon them. For example, Thingiverse is one of the largest and most well-known online repositories of open-source 3D designs. A quick search of the website (www.thingiverse.com) shows designs for everything from prosthetic devices to footwear to toys.

The sharing culture that comprises the maker movement has wider effects in that many technology companies make their software and hardware open source:

> Open-source hardware shares much of the principles and approach of free and open-source software. In particular, we believe that people should be able to study our hardware to understand how it works, make changes to it, and share those changes. To facilitate this, we release all of the original design files (Eagle CAD) for the Arduino hardware. These

files are licensed under a Creative Commons Attribution Share-Alike license, which allows for both personal and commercial derivative works, as long as they credit Arduino and release their designs under the same license. The Arduino software is also open-source. (Arduino, n.d.)

The bottom line is that educators in both formal and informal settings would be foolish not to take advantage of this plethora of resources, tools, and strategies that currently exist.